# Set 28: Reaction Rates

**Skill 28.01: Describe the conditions necessary for molecules to react**
**Skill 28.02: Define activation energy and its affect on reaction rate**
**Skill 28.03: Be able to draw and interpret energy diagrams for reactions**
**Skill 28.04: Explain how changes in *rate-influencing factors* affect reaction rates**
**Skill 28.05: Define catalyst and how they affect reaction rates**

## Skill 28.01: Describe the conditions necessary for molecules to react

### Skill 28.01 Concepts

Reactions between ions of the same charge and between molecular substances are not instantaneous. The electron clouds of molecules repel each other. Therefore, in order to react the molecules must have:

- Favorable orientation
- Sufficient energy to overcome the repulsion forces of the valence electrons

## Skill 28.02: Define activation energy and its affect on reaction rate
## Skill 28.03: Be able to draw and interpret energy diagrams for reactions

### Skills 28.02 & 28.03 Concepts

**Activation energy**, $E_a$, is the minimum energy required to activate a reaction. For the hypothetical one-step reaction:

$A + B \rightarrow C$

The minimum energy required to activate the forward reaction is represented by transition 1 in figure 1.. The minimum energy required to activate the reverse reaction ($C \rightarrow A + B$) is represented by transition 2 in figure 1.

**The lower the activation energy, the more quickly the reaction will proceed.** Because its activation energy is lower, initially the forward reaction, $r_f$, ($A + B \rightarrow C$), will proceed more quickly than the reverse, $r_r$ ($C \rightarrow A + B$). At equilibrium, the rate of the forward reaction is equal to the rate of the reverse reaction, $Rate_{forward} = Rate_{reverse}$.

The heat of the reaction, $\triangle E_{rxn}$, is the energy absorbed or released during the reaction process process. $\triangle E_{rxn}$ is represented by 3. Notice that $\triangle E_{rxn}$ is independent of the activation energy required. $\triangle E_{rxn}$ only depends on the energy of the reactants and products before and after the reaction respectively or

$$\triangle E_{rxn} = \triangle E_{products} - \triangle E_{reactants}$$

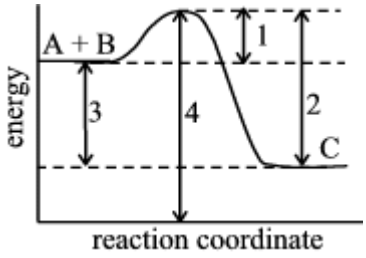

Figure 1.

The **activated complex** is the transitional structure that results from an effective collision. The activated complex forms at the peak of the activation energy. Its location on the energy diagram is at the top of 4. The exact structure of the complex is not known.

**Skill 28.02 & Skill 28.03 Problem 1**

<table>
<tr><td colspan="2">Draw and label energy diagrams depicting the following reactions.</td></tr>
<tr><td>(a) $\triangle E_{forward}$ = -30 kJ ; $E_a$ (forward) = +50 kJ</td><td>(b) $\triangle E_{reverse}$ = +40 kJ ; $E_a$ (forward) = +30 kJ</td></tr>
<tr><td colspan="2">Which reaction proceeds more quickly in the forward direction? How do you know?</td></tr>
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## Skill 28.04: Explain how changes in *rate-influencing factors* affect reaction rates

**Skill 28.04 Concepts**

Any change in reaction conditions that affects the collision frequency, the collision efficiency, or the collision energy affects the reaction rate.

- The rate of the reaction depends on the particular reactants and bonds formed
- The rate of the reaction depends on the area of contact of the reaction substances. Therefore the surface area of the solid reactant is an important factor in determining the rate. **An increase in surface area always increases the rate.**
- The rate of the reaction depends on the temperature. At higher temperatures:
  - More particles possess enough energy to form the activated complex.
  - Collisions occur more frequently.

  **Although increasing the temperature always increases the rate, it does not determine the amount of product formed.**
- The rate of the reaction depends on the concentration of the reactants.

  **In a multi-stepped reaction, the rate of the overall process is limited by the slowest step (or the step with the highest activation energy).**

**Skill 28.04 Problem 1**

For the exothermic rxn represented below, carried out at 298 K, predict the effect of each of the following changes on the initial rate of the reaction and explain your prediction.

$H_2(g) + I_2(g) \rightarrow 2HI(g)$

(a) Addition of hydrogen gas at constant temperature and constant volume.

(b) Increase in volume of the reaction vessel at constant temperature.

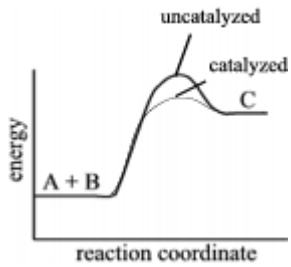
(c) Increase in temperature.

## Skill 28.05: Define catalyst and how they affect reaction rates

**Skill 28.05 Concepts**

A catalyst is a substance that increases the rate of a chemical reaction without itself being permanently consumed.

**A catalyst lowers the activation energy.** The effect of a catalyst is diagramed below.




Because $\triangle H_{rxn}$ does not depend on the reaction pathway, a catalyst has no effect on resulted energy absorbed or released during a chemical reaction.

**Skill 28.05 Problem 1**

The decomposition of compound X is an elementary process that proceeds as follows:

$X(g) \rightleftharpoons A(g) + B(g)$ $\quad\quad$ $\triangle H = +15$ kilocalories

The forward reaction is slow at room temperature but becomes rapid when a catalyst is added.

(a) Draw the diagram of potential energy vs. reaction coordinate for the uncatalyzed reaction. On this diagram label:

(1) the axis
(2) the energies of the reactants and the products
(3) the energy of the activated complex
(4) all significant energy differences

(b) On the diagram indicate the change or changes that result from the addition of the catalyst. Explain the role of the catalyst in changing the rate of the reaction.